Endovascular Treatment in Direct Carotid Cavernous Fistula

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Introduction

Direct carotid cavernous fistula (CCF) is the most common types of arteriovenous fistula (AVF) in the craniofacial area and endovascular treatment is primarily indicated in managing the disease. CCFs are abnormal, direct communications between the internal carotid arteries (ICA) and the cavernous sinuses formed as a consequence of blunt head trauma [1,2]. They occur secondary to traumatic laceration of the internal carotid artery at the intracavernous segment or from rupture of intracavernous branches. AVFs supplied by external carotid artery and dural branches of ICA are traditionally called indirect, or dural arteriovenous fistula of the cavernous sinus and are totally different entity with different therapeutic strategy.

To understand the clinical and angiographic features and to treat this lesion properly, knowledge of vascular anatomy of the skull base and clinical features of this disease are necessary. Angiographic evaluation of the lesion, therapeutic strategies, and treatment-related problems will be discussed.

Vascular Anatomy and Clinical Features

The cavernous sinuses are extradural parasellar venous sinuses and receive drainage from the orbit, cranial base and parasylvian brain via the sphenoparietal sinus (superficial sylvian vein) and normally give drainage down to the internal jugular vein through the inferior petrosal sinus. Bilateral cavernous sinuses communicate through the coronary sinuses, transversely interposed on the anterior, inferior, and posterior to the sella turcica.

Before entering the middle cranial fossa, the internal carotid artery traverses the cavernous sinus with its adventitia being bathed with venous blood. During the course, the artery is in close relation with the cranial nerves (III, IV, VI), which pass through the cavernous sinus. The intracavernous segment of the internal carotid artery is fixed to the surrounding dura at the skull base and is exposed to shearing stress [1,2].

Laceration of the artery and subsequent fistula result in increased pressure of the cavernous sinus and reversal of the venous drainage. Every clinical manifestation and complication of the fistula is related to the reversal of the venous flow and increased pressure of the venous system. Anterior venous drainage of the fistula to the ophthalmic veins produces orbital symptoms such as proptosis, chemosis, secondary glaucoma and decreased visual acuity, and these orbital symptoms are the most frequent clinical problems (figure 1A).

Orbital bruit is the most constant clinical feature in cases with anterior venous drainage. The bruit can be heard with a stethoscope over the involved orbit in almost every case with anterior venous drainage. The pulsatile bruit usually disappears with manual compression of the ipsilateral carotid artery. Observation of a bruit is an important component of management, as it represents a noninvasive means for assessment of either an occlusion or recurrence of the fistula during endovascular treatment.

The fistula may drain posteriorly to the inferior or superior petrosal sinus (figure 1A). Posterior venous drainage produces pulsatile tinnitus due to bone conduction of the increased venous flow. All the signs and symptoms of the lesion can be produced on the contralateral side since both cavernous sinuses communicate with each other.

In the presence of venous hypertension, decreased visual acuity can result from the production of glaucoma due to decreased vitreous drainage into the hypertensive venous system. Visual decline can be fulminant, and progressive decline of visual acuity necessitates urgent treatment of the fistula.

The petrosal sinuses are very closely located with III, IV, V1, and VI cranial nerves just before entering the cavernous sinus. The cranial nerves (III, IV, VI, and VI) can be impaired as they course in the cavernous sinus. Symptoms may occur at the time of trauma by a direct nerve injury or they may be delayed due to a continuous pulsatile trauma within the arterialized cavernous sinus, compression of the nerves by the dilated venous sinuses, or arterial steal of the blood supply to the cranial nerves. Delayed manifestation of the cranial nerve dysfunction has a higher chance of recovery after treatment of the fistula.

Superior venous drainage to the sphenoparietal sinus involves cortical venous routes and may cause transmedullary venous reflux and congestion (figure 1A). Though cerebral symptoms are unusual in CCFs, they are a particular risk in high-flow lesions. Massive intracerebral or subarachnoid haemorrhage rarely results from rupture of the arterialized cortical vein. Although haemorrhagic complication is rare (about 2%), the outcome of complicated subarachnoid haemorrhage is usually fatal. Patients with angiographic evidence of a pseudoaneurysm have a grave prognosis and should receive urgent treatment. Headache is a common clinical manifestation.

This may be related to dural stretching of the cavernous sinus, pulsatile trauma of the trigeminal nerve or venous thrombosis. Headache can be persistent after successful endovascular treatment but is usually relieved in a few days.

Considering the angiographic and clinical findings, the patients with the following findings should be given urgent treatment to prevent serious complication or permanent neurologic deficit:

1) presence of a traumatic pseudoaneurysm,
2) large varix of the cavernous sinus,
3) venous drainage to the cortical vein,
4) thrombosis of venous outflow pathways distant from the fistula,
5) increased intracranial pressure,
6) rapidly progressive proptosis,
7) diminished visual acuity,
8) haemorrhage,
9) and transient ischemic attacks [3,4].

Angiographic Evaluations

Angiographic protocol should include the internal carotid, vertebral, and external carotid arteries on the same side as the fistula. In addition to visualizing direct communication of the internal carotid artery and cavernous sinus, vascular abnormalities associated with trauma, variations of the circle of Willis, anomalous branches or communications (embryonic vessels), and involvement of the external carotid branches should be evaluated on selective angiography.

The summary of protocol for angiographic evaluation is as follows:

1) Ipsilateral internal carotid artery injection confirms the fistula and its venous drainage. It also shows the degree of distal haemodynamic steal (figure 1A). The venous phase of the injection should also be evaluated to assess venous hypertension of the brain.

2) Ipsilateral external carotid artery (lateral view) injection may opacify the fistula if the ruptured vessel is part of the inferolateral trunk. The ophthalmic artery may be opacified better by a internal maxillary injection with less superimposition of venous structures.

3) Vertebral artery (dominant side, lateral view) injection may show the exact level of the fistula with retrograde opacification of the posterior communicating artery and the internal

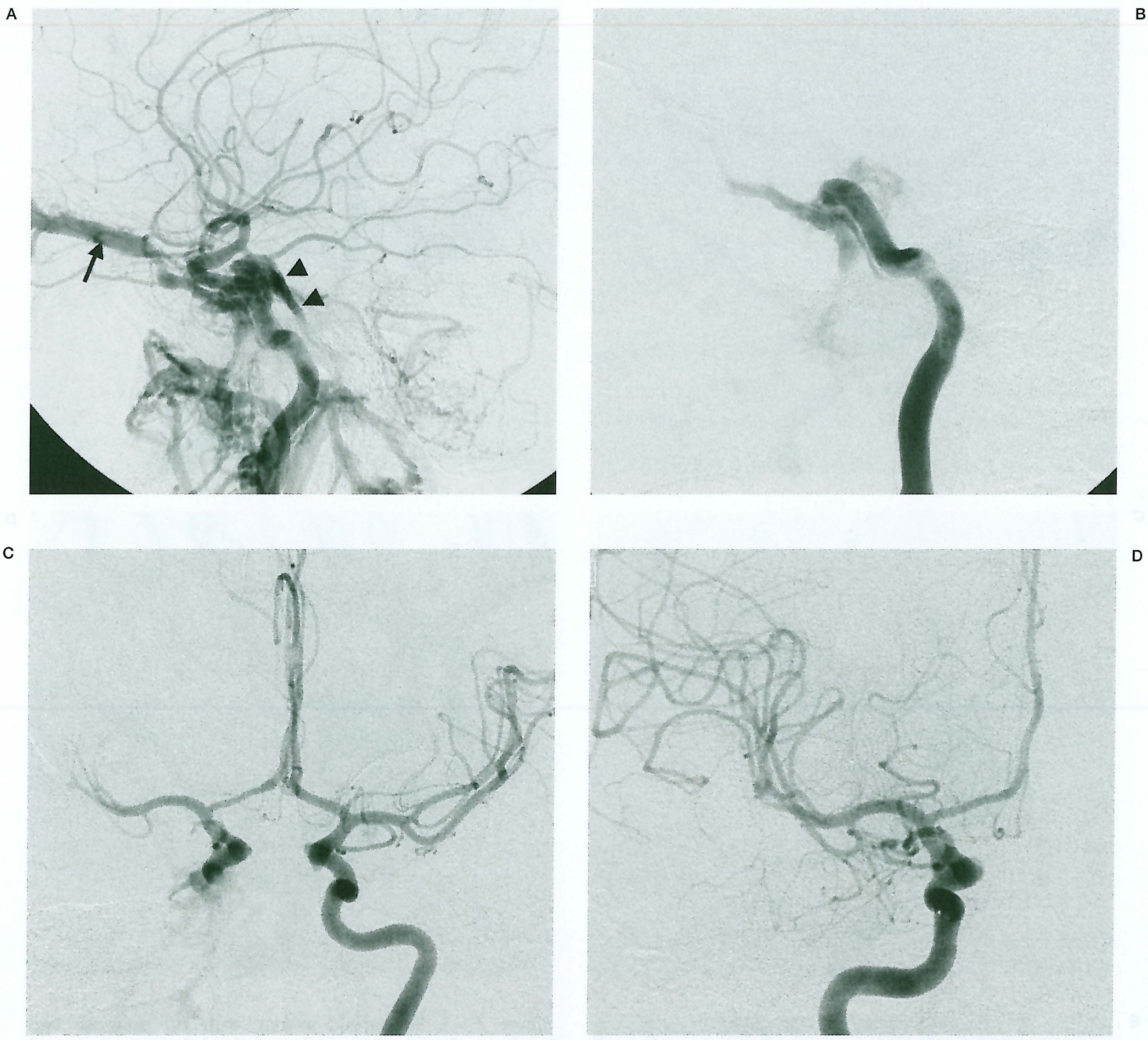


Figure 1 A 35-year-old man with direct carotid cavernous fistula following a motor vehicle accident presented with proptosis and chemosis of the right eye. The arterial phase of the right internal carotid arteriography A) shows a large amount of fistula opacifying the superior ophthalmic vein (solid arrow) and the inferior petrosal sinus (arrowheads) draining to the internal jugular vein. Reflux via the superior petrosal sinus to the cerebellar cortical veins are also seen. The level of the fistula is clearly seen on the right internal carotid arteriography with manual compression of the ipsilateral carotid artery B) and the left internal carotid arteriography with right carotid compression. C) A number 17 latex detachable balloon was passed through the fistula and inflated with diluted contrast media. Post-treatment angiography D) of the right internal carotid artery shows complete occlusion of the fistula. The orbital symptoms disappeared completely in two days.

carotid artery (figure 1D). Vertebral artery injection with manual compression of the ipsilateral internal carotid artery permits a retrograde flow to the fistula, and the precise localization of the lesion can be determined more easily. During the vertebral injection, presence of embryonic communication may be encountered (figure 2).

4) Contralateral internal carotid artery (frontal view) injection is used to assess the status of the anterior segment of the circle of Willis (figure 1C).

When cross filling through the anterior communicating artery is poor, another injection with manual compression of the diseased carotid artery is necessary. This injection may

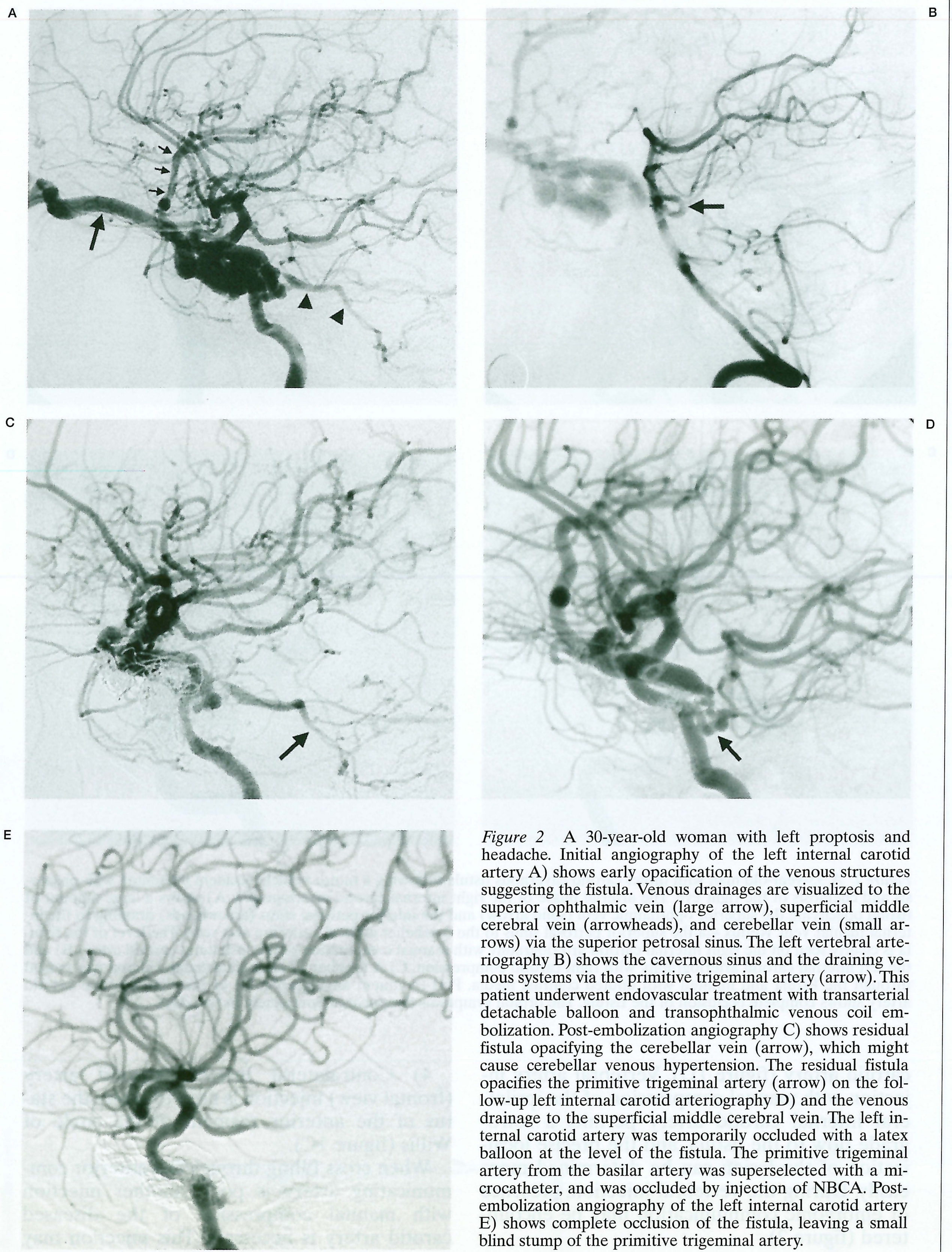


Figure 2 A 30-year-old woman with left proptosis and headache. Initial angiography of the left internal carotid artery A) shows early opacification of the venous structures suggesting the fistula. Venous drainages are visualized to the superior ophthalmic vein (large arrow), superficial middle cerebral vein (arrowheads), and cerebellar vein (small arrows) via the superior petrosal sinus. The left vertebral arteriography B) shows the cavernous sinus and the draining venous systems via the primitive trigeminal artery (arrow). This patient underwent endovascular treatment with transarterial detachable balloon and transophthalmic venous coil embolization. Post-embolization angiography C) shows residual fistula opacifying the cerebellar vein (arrow), which might cause cerebellar venous hypertension. The residual fistula opacifies the primitive trigeminal artery (arrow) on the follow-up left internal carotid arteriography D) and the venous drainage to the superficial middle cerebral vein. The left internal carotid artery was temporarily occluded with a latex balloon at the level of the fistula. The primitive trigeminal artery from the basilar artery was superselected with a microcatheter, and was occluded by injection of NBCA. Post-embolization angiography of the left internal carotid artery E) shows complete occlusion of the fistula, leaving a small blind stump of the primitive trigeminal artery.

demonstrate the fistula by retrograde filling. Retrograde filling of the ipsilateral internal carotid artery in vertebral or contralateral internal carotid injection usually demonstrates the fistula more clearly than does ipsilateral internal carotid arteriography. When these studies cannot demonstrate the exact level of the fistula, additional injections may be necessary. Ipsilateral internal carotid injection with manual compression of the ipsilateral carotid artery and injection of small amounts of contrast media (2 mL per second) can show the fistula more clearly (figure 1B).

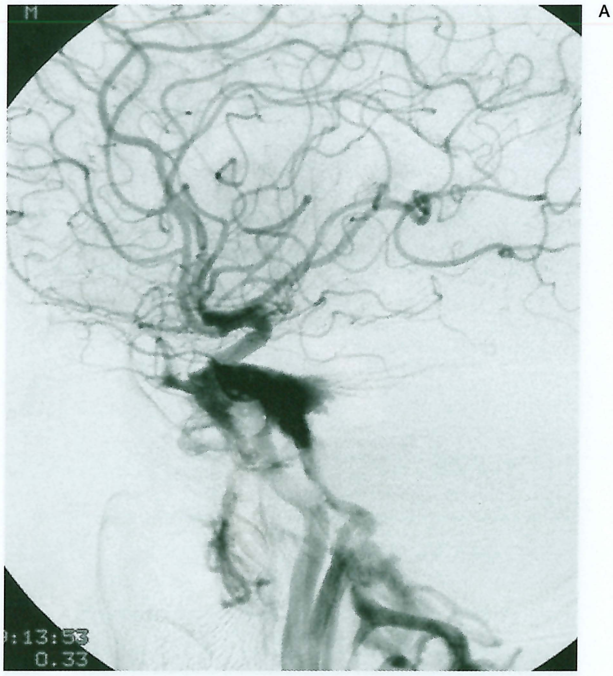
Therapeutic Strategies

Since the introduction by Serbinenko of the concept of using detachable balloons to occlude arteriovenous fistulas and the development of the latex detachable balloon system by Debrun et al, the detachable balloon technique has become by far the treatment of choice in the management of CCFs. With the development of various embolic devices and equipment, there is practically no therapeutic option other than endovascular treatment techniques to treat CCFs [5].

Treatment of CCF is directed to relieve the symptoms of and to eliminate the fistula. The most satisfactory and well-established treatment modality is the placement of a detachable balloon across the fistula using flow direction from the arterial side (figure 1).

The balloon is then inflated within the cavernous sinus so that it can create a tamponade of the fistula, eliminating flow across the fistula and permitting healing of the orifice of the fistula. Two types of detachable balloon can be used in this technique: latex (Debrun type) and silicone (Hieshima type) balloons. While silicone balloons have a lower profile than that of latex balloons, latex balloons have more elasticity. Various kinds of delivery catheters can be used to mount detachable balloons.

Dramatic clinical results with immediate relief of orbital symptoms and bruit are obtained if treatment is adequately performed. Proptosis and chemosis usually disappear in a few days. One can confirm the occlusion of the fistula either by disappearance of the bruit or angiographic disappearance of the fistula during the treatment. It has been said that the fistulas can be cured in about 90% of all CCFs using the



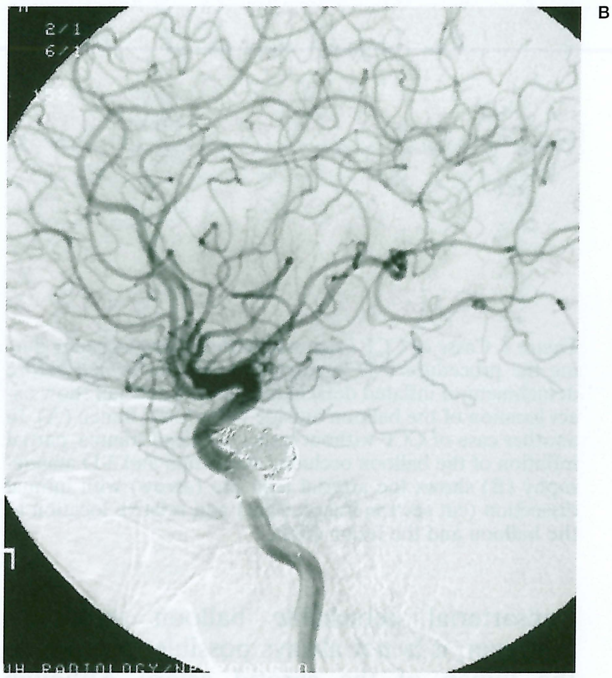


Figure 3 A 20-year-old man with recurrent orbital symptoms on the right side and subjective pulsatile bruit three days after initial treatment with a detachable balloon. Right internal carotid arteriography A) shows recurrent fistula with venous drainage to the ophthalmic veins and the inferior petrosal sinus. The residual opening of the fistula was too small for a detachable balloon to pass through into the cavernous sinus. The fistula was occluded with multiple platinum coils and post-treatment angiography B) of the right internal carotid artery shows successful occlusion of the fistula.

A

B

C

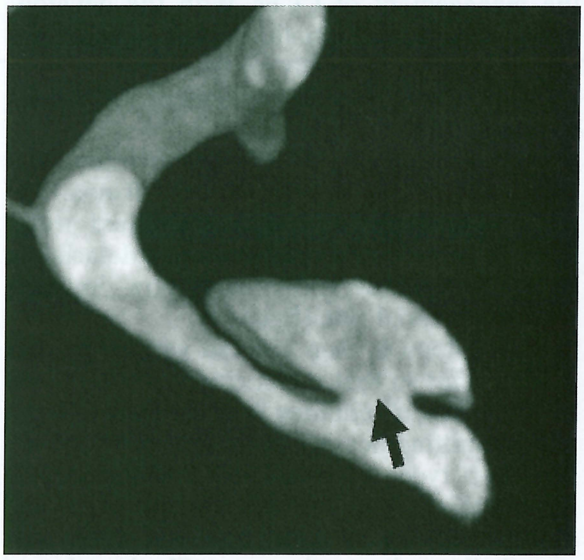


Figure 4 Casse of CCF examined with 3-D angiography during the procedure. 3-D angiography was performed before detachment of inflated detachable balloon and can show exact location of the balloon outside the arterial lumen (A). In another case of CCF without history of head trauma, partial inflation of the balloon occluded the fistula and 3-D angiography (B) shows the arterial tear site (arrow) with intimal dissection (cut section image, right) and relative location of the balloon and the lesion (right).

transarterial detachable balloon technique. However, it is not always possible to preserve the lumen of the carotid artery. Although preservation of the carotid blood flow is one of the main advantages of this technique, most authors of the largest series in the literature have reported a preservation rate of the carotid lumen between 60% and 70%. For occluding the fistula with a markedly dilated cavernous sinus, multiple balloons are frequently used.

In some instances, the carotid artery can be occluded intentionally to treat the fistula. In cases of severe arterial damage with irregular laceration or dissection, the lumen of the internal carotid artery may be intentionally sacrificed with the balloon along with the fistulous opening.

Before permanent occlusion of the artery, one should evaluate collateral channels and perform an occlusion tolerance test. As mentioned earlier, coexistence of a pseudoaneurysm is an indication for urgent treatment to prevent massive fatal epistaxis. When treating the lesion with a pseudoaneurysm, the internal carotid artery is usually sacrificed intentionally.

In some cases with a small fistulous opening, low-flow fistula, or difficult direction of the fistula, it may be technically impossible to pass a detachable balloon through the fistula. Other embolic devices such as thrombogenic microcoils can be used in these cases.

The fistulas can be directly selected with wire-guided microcatheters, and the fistulas can be occluded with various microcoils (figure 3). This technique can be used either transarterially or transvenously[6,7].

Transarterial technique is usually easier than transvenous way and is usually chosen first. One of the most sophisticated devices is the Guglielmi detachable coil (GDC) originally developed for the treatment of intracranial aneurysm (figure 3). For transarterial coil embolisation, using fibered GDC is preferred for effective occlusion of the fistula with enhanced thrombogenicity.

Techniques and Complications of Endovascular Treatment

A latex balloon can be inflated with diluted water-soluble contrast media. Contrast-filled latex balloons will eventually deflate in several weeks, and the fistulas usually heal during this period.

The deflation of the balloons after healing of the fistulas might leave venous pouches, like pseudoaneurysms, usually without symptoms. Early deflation or displacement of the balloons before complete healing of the fistula may cause recurrence of the CCF. With experience of our series of 120 patients, the recurrent fistula can occur within one week after detachable balloon treatment. There has been no case of recurrence after one week. It is thought that this period of one week may be sufficient for healing of the fistula.

Technical problems of detachable balloon occlusion in CCFs include premature detachment, premature deflation, unsatisfactory placement of a balloon, rupture of a balloon during manipulation, and difficulty in detachment or deflation of a balloon[6]. Before detaching the balloon occluding the fistula, multiple angiographic confirmation of the extra-arterial location of the balloon is very important. When inflating the initial balloon, the pressure gradient between the carotid artery and cavernous sinus may make the balloon attach to the fistulous opening inside the arterial lumen occluding the fistula. Careful evaluation of the angiography obtained before detachment is necessary to prevent intraluminal migration of the balloon after detachment and subsequent occlusion of the internal carotid artery. Recently developed 3-D angiography can show the position of the balloon precisely before detachment (figure 4).

In some cases with large fistula, the balloon can be displaced during detachment. Occlusion balloon catheter can be used for preventing balloon displacement during detachment. In some instances, single detachable balloon cannot occlude the fistula completely. In this situation, subsequent one or more balloons can be used. Using the second femoral route, the second balloon should be navigated through the fistula before the first balloon detached. With manipulating two balloons simultaneously, adjusting the volumes and changing the positions of the balloons, one can easily occlude the fistula completely.

There may be complications related to the procedure. Thromboembolic complication may occur during the procedure, and the patients should be heparinized systemically. Premature detachment of a balloon within the cavernous sinus does not produce any problem, but an inadvertently detached balloon in the arterial lumen may cause ischemic complication. An inflated balloon within the cavernous sinus may cause delayed cranial neuropathy by direct compression of the cranial nerve. It is necessary to perform a pre-detachment angiography and to examine the patient carefully before detachment of a balloon.

We have experienced one case of delayed third cranial nerve palsy of our series of 120 cases. Residual fistula after treatment to the inferior petrosal sinus leaves subjective bruit and usually causes no complication.

However, residual cortical venous drainage after occlusion of the ophthalmic or petrosal drainages may change the direction of the venous drainage and may cause venous hypertension.

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